Method of depositing an oxidation and fatigue resistant MCrAlY-coating

FIELD OF INVENTION

This invention relates according to claim 1 to a protection of gas turbine blades and vanes against oxidation and thermal mechanical fatigue by using MCrAlY overlay coatings deposited by an electroplated process.

STATE OF THE ART

The turbine blades and vanes designed for use at high temperature are usually coated with environmentally resistant coatings. For example, MCrAlY overlay coatings are used for protection of turbine blades and vanes. MCrAlY protective overlay coatings are widely known in the prior art. They are a family of high temperature coatings, wherein M is selected from one or a combination of iron, nickel and cobalt. As an example US-A-3,528,861 or US-A-4,585,481 are disclosing such kind of oxidation resistant coatings. US-A-4,152,223 as well discloses such method of coating and the coating itself. Besides the γ/β-MCrAlY-coating, there is another class of overlay MCrAlY coatings which are based on a γ/γ'-gamma/gamma prime-structure, which is for example disclosed in US-A-4,546,052 or US-A-4,973,445. The advantages of γ/γ'-coatings is that they have a negligible thermal expansion mismatch with alloy of the underlying turbine article and are likely to have a better thermal mechanical properties.

Among γ/γ'- and γ/β-coatings, the field of γ/β-coatings have been an active area of research and a series of patents has been issued. E.g. a NiCrAlY

coating is described in US-A-3,754,903 and a CoCrAlY coating in US-A-3,676,058. US-A-4,346,137 discloses an improved high temperature fatigue resistance NiCoCrAlY coating. US-A-4,419,416, US-A-4,585,481, RE-32,121 and US-A-A-4, 743,514 describe MCrAlY coatings containing Si and Hf. US-A-4,313,760 discloses a superalloy coating composition with good oxidation, corrosion and fatigue resistance. Additional examples MCrAlY coatings are known from US-B1-6,280,857, US-B1-6,221,181, US-A-5,455,119, US-A-5,154,885, US-A-5, 035,958 or US-B1-6,207,297. They all deal primarily with improving the oxidation resistance of MCrAlY coatings.

Thermal barrier coatings are used to provide thermal insulation of the components in various types of engines e.g. in turbine engines. Furthermore, in the state of the art Thermal Barrier Coatings (TBC) are known from different patents. US-A-4,055,705, US-A-4,248,940, US-A-4,321,311 or US-A-4,676,994 disclose a TBC-coating for the use in the turbine blades and vanes. The ceramics used are yttria stabilized zirconia and applied by plasma spray (US-A-4, 055,705, US-A-4, 248,940) or by electron beam process (US-A-4, 321,311, US-A-4, 676,994) on top of the MCrAlY bond coat.

One major disadvantage of γ/γ'-type of MCrAlY coatings is that due to the low aluminum content they do not form a continuous alumina film at temperatures below 1000°C what leads to a problem with the bonding adherence with the TBC. Therefore US-A-5,894,053 developed a process of forming a roughened surface by applying particulate materials on the surface using binder, principally soldering powder. In recent years, there has been a significant thrust in developing low thermal conductivity ceramics, US-B1-6,365,236, US-B1-6,299,971 and US-B1-6,284,323 and a continuation of efforts in improving the mechanical TBC adhesion by surface roughening. US-A1-2002/0009609, US-A1-2002/0004143, US-A1-2002/0004142, US-A-6,136,453 or US-B1-6,210,812 disclose some examples.

It is generally known in the industry that the coatings on turbine blades or vanes can fail by one or more of the following degradation modes. These are

oxidation, corrosion, TMF (Thermal Mechanical Fatigue) and a combination of TMF and oxidation. Coatings failure in a turbine engine solely by oxidation is not a typical scenario. Further, in advanced turbine engines, incidences of corrosion are not common due to higher engine operating temperature and use of cleaner fuels. What is commonly observed is that the MCrAlY coatings are cracked by TMF. Subsequently the cracks allow oxygen diffuse or penetrate into the substrate. Since the substrate is not oxidation resistant the advancing oxygen (through the cracks) causes the oxidation of the underlying substrate and triggers the failure of the components. It is therefore important that the coatings be resistant to fatigue as well as oxidation since fatigue cracking appears to be one of the primary triggering mechanisms of the failure of the coatings.

One approach of improving the fatigue resistance of coatings is by modification of the composition of the coatings and secondly by the use of a thin coating or possibly a combination of both.

US-A-4,346,137 and US-A-4,758,480 described a method of improving the fatigue resistance of overlay coatings by a modification of composition. In US-A-4, 346,137, the platinum was added to MCrAlY coatings, which reduces the thermal expansion mismatch between the coatings and the substrate, hence also reduces the propensity of the coatings to cracking. This results in a significant improvement of the TMF life of the coatings. On the other hand, the US-A-4,758,480 discloses a class of protected coatings for superalloys in which the coating compositions are based on the composition of the underlying substrate. By tailoring the coatings to the substrate composition, diffusional stability results and other mechanical properties of the coating such as coefficient of thermal expansion and modulas, are brought closer to the substrate. The coatings thus obtained have not only increased oxidation resistance and diffusional stability but also exhibit a substantially higher TMF life.

The increase of coating thickness decreases TMF life of coatings. The problem is then to find a method that allows a deposition of thin protective coatings on complex turbine airfoils. A literature search shows that the MCrAlY overlay

coatings are generally deposited by plasma spray process (i.e. APS, VPS, LPPS or HVOF). Although not widely used, there is also other manufacturing process; examples are electron beam physical vapor deposition (EB-PVD) and sputtering. However, there are limitations of these processes; a) difficult or unable to deposit a thin coating uniformly, b) poor thickness control and c) a line of sight limitation. Since airfoils contain many complex contoured surface i.e. airfoil to platform transition area, leading edge etc., the line of sight limitation present a difficulty in getting a good uniform coverage of coatings with microstructural integrity.

Interestingly, in a series of patents, US-A-5,558,758, US-A-5,824,205 and US-A-5,833,829 described the deposition of MCrAlY coatings by electroplated process. The process involves a deposition of the coating precursor, CrAlM2 powder in a M1 bath where M2 is one or more of Si, Ti, Hf, Ga, Nb, Mn, Pt and rare earth elements and M1 consists of Ni, Co, Fe alone or in combination. The as-deposited coating is heat-treated to obtain the final coating structure.

SUMMARY OF THE INVENTION

The objective is to find a MCrAlY-bond or overlay coating with good oxidation and fatigue resistance. Another object of the present invention to find a method of depositing a MCrAlY-coating on a turbine component with uniformity. Yet another object of the invention is to deposit a thin MCrAlY-coating on a large industrial gas turbine blade or vane with a good thickness control of the deposited layer. Another object is to deposit the MCrAlY-coatings on a component with a good microstructural conformity and metallurgical integrity.

According to the invention a method of deposition a MCrAlY-coating by means of an electroplated process was found according to features of the claim 1 or 2.

It is noted that the cost of the application of a coating by an electroplated process is considerably lower than by a conventional plasma spray coating. In

addition, the electroplated process has a thickness control of ±20 μm or better, whereas conventional plasma spray coating processes have thickness scatters of ±75 μm or even more. Thus, a coating with a layer thickness in a range of 25-400 μm can be applied. A thinner coating increase the TMF life of the coating. The used electroplated process has no line of sight limitation and can coat complex contour surfaces without any difficulty. In addition the coating thus manufactured contains very little oxygen impurity. The deposited coating is heat-treated in vacuum, argon, hydrogen at 1140°C for 2 to 12 hours.

An addition of (wt.-%) 0.01 to 3% Fe is provided for increased ductility. An addition of (wt.-%) 0.5-2.5% Si, 0.2-1.5% Hf, 0.01-0.2% Zr or 0-2% Ta either alone or in combination for increased scale adhesion of the deposited coating.

On top of the applied layers a layer of a ceramic thermal barrier coating (TBC) such as yttria-stabilzed zirconia (YSZ) with suitable composition can be applied.

BRIEF DESCRIPTION OF DRAWINGS

Preferred embodiments of the invention are illustrated in the accompanying drawings, in which

Fig. 1 shows a gas turbine blade as an example and

Fig. 2 one embodiment of a MCrAlY-bond-coating on the external surface of the gas turbine blade according to the present invention.

The drawings show only parts important for the invention.

DETAILED DESCRIPTION OF INVENTION

The present invention is generally applicable to components that operate within environments characterised by relatively high temperature, and are

therefore subjected to severe thermal stresses and thermal cycling. Notable examples of such components include the high and low pressure nozzles and blades, shrouds, combustor liners and augmentor hardware of gas turbine engines. Fig. 1 shows as an example such an article 1 as blades or vanes comprising a blade 2 against which hot combustion gases are directed during operation of the gas turbine engine, a cavity, not visible in Figure 1, and cooling holes 4, which are on the external surface 5 of the component 1 as well as on the platform 3 of the component. Through the cooling holes 4 cooling air is ducted during operation of the engine to cool the external surface 5. The external surface 5 is subjected to severe attack by oxidation, corrosion and erosion due to the hot combustion gases. In many cases the article 1 consists of a nickel or cobalt base super alloy such as disclosed, by way of an example, in US-A-5,759,301. In principle, the article 1 can be single crystal (SX), directionally solidified (DS) or polycrystalline. While the advantages of this invention is described with reference to a turbine blade or vane as shown in Fig. 1, the invention is generally applicable to any component on which a coating system may be used to protect the component from its environment.

Example of the invention

As shown in Tab. 1 a series of MCrAlY-coatings were identified and deposited by electroplated process.

	Ni	Co	Cr	Al	Y	Si	Ta	Comment
SE329	Bal.	23	18	10	0.5			Uniform
SE329-1	Bal.	21	21	11.5	0.3			*
SE349	Bal.	30	13	11.5	0.3	1.2	0.5	*
SE349-1	Bal.	24.6	15.3	9.4	0.4	1.2	0.4	*
SE303	Bal.	--	19.5	9.1	0.27	--	--	Coating uniform
SE29-1	Bal.	27.5	18.5	10.19	0.26	--	--	uniform

* powder reacted with the electrolytic bath

Tab. 1

The phase and diffusional stability of the coatings in Table 1 were calculated using the DICTRA software package developed by Thermo-Calc Software, Sweden. The coatings were applied according to the procedure outlined in US-A-5,558,758, US-A-5,824,205 and US-A-5,833,829. Both coating heat-treatment and compositional adjustments are often necessary for homogenization of composition-microstructure i.e. complete reactions of 'CrAl' particles with the matrix. The coatings deposited provided good oxidation resistance, for example, the SE329 formed α-alumina scale in the temperature range 800-1100°C.The TMF life of the coating was determined in a strain-controlled test, open cycle, 800-100°C and 1000-100°C, with a dwell time at maximum temperature of 5 minute. The TMF-life of the SE329-coating was compared with plasma sprayed coatings described by US-A-6,221,181. The TMF life of the electroplated coating was at least 2 times higher than the life of the plasma sprayed coatings. It is to be stated that the thickness of the electroplated SE329 was 220 ±20 μm, the baseline plasma spray coating was nominal 300 μm thick with a plasma spray coating thickness scatter of at least ±75 μm. Thus, a coating with a layer thickness in a range of 25-400 μm can be applied. A thinner coating increase the TMF life of the coating. It is noted that the cost of the application of a coating by an electroplated process is a third of a conventional plasma spray coating cost. The used electroplated process has no line of sight limitation and can coat complex contour surfaces without any difficulty. In addition the coating thus manufactured contains very little oxygen impurity. The oxygen impurity is known to adversely affect the fatigue life of coatings. The deposited coating is heat-treated in vacuum, argon, hydrogen at 1140°C for 2 to 12 hours.

It is believed that the TMF life of the coatings, for example, improved TMF life of SE329 was probably due to a combination of a) a leaner coating b) the coating composition, c) the microstructure and heat-treatment and d) low oxygen content of the coating. The SE329 coating was successfully manufactured by an electroplated process on low pressure turbine blades. The deposited coating on the blade was uniformly distributed over external sur-

faces including the airfoil-platform transition area, fillet, leading and trailing edge.

Fe is added (wt.-%) 0.01 to 3% in order to enhance the ductility of the coatings while the additions of 0.5-2.5% Si, 0.2-1.5% Hf, 0.01-0.2% Zr or 0-2% Ta either alone or in combination are provided for increased oxidation resistance of the deposited coating.

As seen in Fig. 2 the layer of MCrAlY-coating 6 was deposited on the external surface of the article 1. The layer 6 was deposited as bond coating with a layer of a ceramic coating 7 such a ceramic thermal barrier coating (TBC) on top of the bond layer 6. As TBC yttria-stabilzed zirconia (YSZ) with suitable composition being about 4 to 20 wt.-%, though other ceramic materials could be used, such as yttria, non-stabilzed zirconia, or ceria (CeO_2), scandia (Sc_2O_3) or other oxides. The ceramic layer 7 is deposited to a thickness that is sufficient to provide the required thermal protection for the underlying substrate, generally in the order of about 300-600μm.

While our invention has been described by an example, it is apparent that other forms could be adopted by one skilled in the art. Accordingly, the scope of our invention is to be limited only by the attached claims.

REFERENCE NUMBERS

1	Article
2	Blade
3	Platform
4	Cooling holes
5	External surface of article 1
6	Layer of MCrAlY
7	Layer of ceramic coating